Tracking Operations During the Viking 1 Launch Phase

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Viking 1 launch phase tracking operational procedures were intensively considered and conservatively designed to accommodate even the most unfavorable of launch possibilities. These procedures were successfully implemented and strongly contributed to the highly successful launch of Viking 1. This report details the prelaunch planning for and subsequent analysis of tracking operations during the Viking 1 launch phase.

I. Introduction

The Viking 1 spacecraft was launched from the Air Force Eastern Test Range (AFETR) on August 20, 1975, at 21:22:00.632 Greenwich Mean Time (GMT), and at a launch azimuth of 96.57 degrees. The purpose of the Viking 1 mission is to study the planet Mars via direct measurements in its atmosphere, on its surface, and in orbit about it. To accomplish this goal, the Viking 1 spacecraft was lofted into a trans-Mars, heliocentric orbit by a combination Titan III-E/Centaur D-1T launch vehicle in the parking orbit ascent mode. Trans-Mars orbital injection occurred over southern Africa, and the resulting near-Earth portion of the orbit was such that within the Deep Space Network (DSN), the Australian complex was the first to view the spacecraft post-injection. The Deep

Space Station (DSS) selected to perform the initial acquisition was DSS 42 (Weemala, Australia) with DSS 44 (Honeysuckle Creek, Australia) as backup.

In the following sections, the prelaunch tracking operations planning and the subsequent analysis of launch phase tracking operations at these stations will be detailed.

II. Viking 1 Trajectory Considerations

The open window Viking 1 launch trajectory for August 20 resulted in angle and frequency rates which were quite small, even when compared to previous (but otherwise similar) mission parking orbit ascent type launch trajectories over Australian stations. Maximum

angular and frequency rates were as follows:

$$\frac{d}{dt}\{D2\} \approx 80 \text{ Hz/s (S-band)}$$

$$\frac{d}{dt}\{XA\} \approx 0.4 \text{ Hz/s (VCO level)}$$

$$\frac{d}{dt}\{HA\} \approx 0.04 \text{ deg/s}$$

where

$D2$ = two-way doppler frequency

XA = spacecraft receiver best lock, with doppler accounted for

HA = local (station) hour angle

Figure 1 stereographically illustrates the Viking 1 launch pass over DSS 42, while Fig. 2 details the elevation angle versus time and Fig. 3 the XA frequency versus time. Additionally, Fig. 2 serves as a time line for the important tracking events at DSS 42. The pass was approximately 5 hours 15 minutes long, with the retrograde point, defined by

$$\frac{d}{dt}\{HA\} = 0$$

occurring at approximately 23:16:00 GMT and at an HA of

$$HA \cong 47.7 \text{ deg}$$

A facet of information necessary to the determination of the initial acquisition strategy for the Viking 1 launch was the expected uncertainties in tracking observables as translated from the expected uncertainties in the launch vehicle performance. The Viking Flight Path Analysis Group (FPAG) provided a typical 3σ perturbed trajectory and the corresponding nominal trajectory. Tracking observable predictions were then generated from both trajectories and, when differenced, yielded the following maximum 3σ uncertainties in tracking parameters for DSS 42:

$$\Delta HA \approx 0.002 \text{ deg}$$

$$\Delta D2 \approx 10 \text{ Hz (S-band)}$$

$$\Delta XA \approx 0.05 \text{ Hz (VCO)}$$

These numbers are miniscule and are, in fact, smaller by orders of magnitude than assumed trajectory uncertainties for previous mission launch phases. For instance, the equivalent numbers for the Helios 1 launch (see Ref. 1) were:

$$\Delta HA \approx 1.15 \text{ deg}$$

$$\Delta D2 \approx 3500 \text{ Hz (S-band)}$$

$$\Delta XA \approx 17 \text{ Hz (VCO)}$$

The impact of the above numbers on the initial acquisition strategy, as well as the results of the actual launch trajectory, will be discussed in later sections.

III. Launch Tracking Predictions

A. New Prediction System

The Network Operations Control Team (NOCT) generates a variety of predict sets[1] during the launch phase which reflect spacecraft frequency updates, different possible trajectories, different remote site uses, etc. Prior to May 15, 1975, predictions were generated via a Probe Ephemeris Tape (PET) produced by the Flight Path Analysis Group (FPAG) on the Univac 1108 computer, in combination with prediction software ("PREDIX") on the IBM 360 computer. Subsequent to May 15, 1975, predictions were and are currently generated via a Polynomial Coefficient Tape (PCT) produced by the FPAG on the Univac 1108 computer, in combination with prediction software ("PREDIK") on the Network Data Processing XDS Sigma-5 computer. Viking 1 thus became the first launch phase to be executed under the PCT/PREDIK system. The major concern with the new system was the throughput time (here defined as the time interval from initiation of a PCT to start of predict transmission to the DSS). The most optimistic forecast of the throughput time for launch predicts was initially:

$$\Delta t \approx 41 \text{ min}$$

Since rise at DSS 42 occurred at approximately L plus 48 minutes, the chances of getting predictions initiated shortly after liftoff and based on the actual liftoff time to DSS 42 prior to rise appeared only marginal. The prediction generation sequence was exercised repeatedly during launch simulations in the months prior to launch, such that at the conclusion of the Operational Readiness Test (ORT) the predict generation process appeared to be optimized and the final throughput time minimized, thereby greatly increasing confidence in the ability to

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[1]Additionally, predictions are also generated at AFETR by the Real Time Computing System (RTCS).

transmit actual liftoff predictions to DSS 42 well ahead of rise. Some partial test results are presented below:

Test/date	PCT generation	PREDIK generation	Total
Forecast	20 M	21 M	41 M
VT1B 6-25-75	—	17 M	—
	25 M	16 M	41 M
	—	13 M	—
	—	22 M	—
DT-1 7-25-75	—	21 M	—
	18 M	20 M	38 M
	18 M	27 M	45 M
	—	16 M	—
ORT-1 8-6-75	—	14 M	—
	16 M	10 M	26 M
	19 M	13 M	32 M
	—	12 M	—
	—	10 M	—

B. Launch Predicts Identification System

During a typical launch phase, numerous predict sets are necessitated due to changes in spacecraft frequencies, trajectories, etc. To allow for immediate recognition of the differing sets of predicts by users within the Network Operations Control Team and at the DSS, a new more informative and systematic code was developed for the four-character alpha-numeric predict identifier. The code is described as follows:

WXYZ = 4-character alpha-numeric predict identifier

with

W = spacecraft identifier: A for Viking 1, and B for Viking 2

XY = launch date/test identifier. For actual launches, XY is the day of the month of the launch, while for launch tests X = T, and Y indicates the particular type of test.

Z = origin or usage of predicts. Z denotes the basis for the data used to generate the predicts, such as nominal open window predicts, actual liftoff predicts, etc., or the intended usage of predicts, such as drive tape predicts, frequency update (text) predicts, etc. A description of the various types of predicts denoted by Z is seen in Table 1.

C. Polynomial Coefficient Tape Generation

The optimum set of (preflight) nominal predicts would be those based on the nominal trajectory corresponding to the actual liftoff time. However, since the actual liftoff time usually varies within a second or two of the scheduled (or rescheduled) liftoff, and, in consideration of the tracking observable errors induced in the predicts as a function of a Δt offset, it was decided that a reasonable goal would be to strive for the generation of a PCT based on a liftoff time within 2 seconds of the actual liftoff time. The Viking FPAG developed a scheme to maximize the possibility of rapidly producing such a PCT, and this scheme is seen in Fig. 4. The PCT numbers in Fig. 4 are identified with the various predict sets as follows:

PCT number	Predict identifier (Z)
1	D, F
2	E
3	E
4	A

IV. Angle Drive Strategy at DSS 42

The relevant considerations, in attempting to formulate the angle drive strategy at DSS 42 for the Viking launch phase were as follows:

(1) Desire to acquire the uplink shortly after rise (at about rise plus 3 minutes).

(2) Requirement for being on Antenna Pointing Subsystem (APS) drive tape during the uplink sweep so as not to drive the antenna off point (in autotrack) when the one-way/two-way downlink switch causes the receivers to drop lock.

(3) High probability (but not certainty) of accurate angle predictions (APS drive tape).

(4) Desire for early acquisition of autotrack data.

(5) Desire to lock the S-band cassegrain monopulse (SCM) feed cone as well as the acquisition aid antenna (SAA) prior to initiation of the uplink sweep.

One obviously achieves the highest probability of being on the spacecraft (and, hence, initially acquiring the one-way downlink) by driving the antenna to the best (drive tape) predictions. However, it was clear from items (1) and (2), above, that there would be insufficient time to acquire one-way on APS drive tape, go to autotrack, and

then return to APS drive tape prior to rise plus 3 minutes. Thus the simplest scheme with a high probability of success in meeting the goals delineated above would be to stay on APS drive tape throughout the two-way acquisition, and then shortly thereafter proceed to autotrack. To facilitate the details of this strategy, two phases were defined:

(1) Phase I: Rise to 2-way acquisition.

(2) Phase II: Post 2-way acquisition.

The hierarchy of preference or required action for each phase, which was heavily dependent on the availability of differing sets of predicts, is presented below:

(1) Phase I—Rise to 2-way acquisition

    (a) Prior to rise, the antenna to be positioned at the rise point of the prime (as defined) prediction set.

    (b) angle drive mode subsequent to predicted rise (in order of preference).

        (i) Applicable condition: launch occurs within 2 seconds of the open window launch time.

        Angle drive mode: a verified drive tape in GMT and based on preflight nominal open window predictions (predict code XXXD; see Section III).

        (ii) Applicable condition: launch does not occur at the open window, but a verified drive tape based on the actual launch time is available at DSS 42 prior to rise.

        Angle drive mode: a verified drive tape in GMT and based on the actual launch time (codes XXXE, XXXA).

        (iii) Applicable condition: launch does not occur at the open window, an actual launch time drive tape is not available before rise, but actual launch time page print (fixed point) predicts are available.

        Angle drive mode: a preflight nominal verified drive tape in time from launch (TFL) with a Δt offset equal to the actual launch time in GMT (predict codes XXXO, XXXM, XXXC). Angle offsets to be calculated and applied to correct the antenna position to the actual launch time page print predictions.

        (iv) Applicable condition: launch does not occur at open window, and neither actual

launch time page print (fixed point) nor APS drive tape predicts (binary) are available at DSS 42 prior to rise.

        Angle drive mode: a preflight nominal verified drive tape in TFL with a Δt offset equal to the launch time in GMT (codes XXXO, XXXM, XXXC). Angle biases to be provided to DSS 42.

(2) Phase II—Post 2-way acquisition

    (a) Acquire and verify receiver lock on the acquisition aid antenna.

    (b) Antenna to autotrack on the acquisition aid antenna.

    (c) Acquire and verify receiver lock on the S-band cassegrain monopulse.

    (d) Antenna to autotrack on S-band cassegrain monopulse.

V. Uplink Acquisition Strategy at DSS 42

The Viking two-way initial acquisition study team, meeting in May/June 1975, formulated two desired guidelines for the initial two-way acquisition:

(1) Start the uplink acquisition at approximately rise plus 3 minutes.

(2) Perform the uplink acquisition on the S-band cassegrain monopulse instead of the more usual acquisition aid antenna.

However, it was subsequently reassessed that item (2), above, might be undesirable for the following reasons:

(1) Because of the slowness of the new PCT/PREDIK prediction system, DSS 42 might not have the correct (and necessary) verified APS drive tape available prior to rise.

(2) Even if item (1), above, were satisfied, the APS drive tape might not be accurate enough for the SCM for any "non-nominal" modes of launch vehicle performance.

(3) Use of the SCM would require transmitter operation and calibration in a region (50 watts) for which it was not designed and where it has only infrequently been used.

(4) Finally, there is (at least theoretically) no perceptible degradation in doppler quality (signature and

noise) when transmitting on the acquisition aid antenna versus the S-band cassegrain monopulse.

In light of the above, the uplink acquisition was planned to be performed on the acquisition aid antenna. The following uncertainty information, as pertained to the uplink, was provided by the Viking Project (all frequencies at S-band):

3σ XA trajectory $\qquad \sim 5$ Hz (from Section II)

3σ XA S/C receiver $\qquad \sim 1500$ Hz

3σ XA S/C "random walk" ~ 750 Hz

3σ XA S/C temperature $\quad \sim 10°F\ (5.6°C)$

$$\frac{\partial XA}{\partial T} \approx 500\ \text{Hz/°F or }900\ \text{Hz/°C}$$

Combining the above, one has for a total 3σ uncertainty:

$$3\sigma\ XA\ \text{total} \sim 5300\ \text{Hz}$$

To be extremely conservative, the above 3σ XA uncertainty was doubled, thus resulting in an uplink acquisition search of approximately $XA \pm 11,000$ Hz.

The Viking spacecraft receiver characteristics indicated an acquisition sweep region bounded by:

$$70\ \text{Hz/s} < \text{frequency rate} < 800\ \text{Hz/s}$$

under conditions of strong signal strength, as would be expected to apply in the initial acquisition. Therefore, a sweep rate of $+300$ Hz/s was selected because:

(1) It was felt that 300 Hz/s was close to the limit at which the site would no longer be able to accurately (manually) tune the exciter.

(2) A rate of $+300$ Hz/s would result in an effective rate at the spacecraft of about $+250$ Hz/s, which is very close to the geometric mean of the upper and lower sweep limits (237 Hz/s).

Finally, the sweep was chosen to be in the direction of XA change so that the end of the sweep would become TSF for the remainder of the pass. This would be advantageous in that no additional tuning (to TSF) would be required, and the spacecraft static phase error (SPE) for the rest of the pass would be reasonably small. Incorporating the above characteristics, the uplink acquisition procedure was planned as follows:

(1) Transmitter to be connected to the acquisition aid antenna and set to radiate at an initial power level of 10 kW.

(2) Transmitter on at (defined) start of uplink sweep minus 20 seconds.

(3) Station to throw 2-way doppler data switch at start of uplink sweep minus 10 seconds (this so that the NOCT can immediately know when (and if) two-way lock is achieved, and if lock is on the main carrier or a sideband).

(4) The uplink sweep to begin at approximately rise plus 3 minutes.

(5) The sweep to cover at least $XA \pm 11,000$ Hz.

(6) The sweep rate to be $+180$ Hz/min (VCO level), which would result in a rate of approximately 250 Hz/s at the spacecraft (receiver rate = sweep rate minus spacecraft rate).

(7) The sweep duration to be 90 seconds.

For the actual launch on August 20, 1975, the uplink acquisition sweep selected according to the above guidelines was as follows:

Sweep start time $= 22{:}14{:}00$ GMT

Start frequency $= 21.996130$ MHz (VCO)

Frequency rate $= 180$ Hz/min (VCO)

Sweep end time $= 22{:}15{:}30$ GMT

End frequency $= 21.996400$ MHz (VCO)

This uplink sweep pattern is seen in Fig. 5.

If the first sweep was not successful, it was planned to execute a second contingency sweep. This sweep would be at the same rate as the prime sweep, but would cover a region approximately 50% greater ($XA \pm 16,500$ Hz). It would start 3 minutes 30 seconds after the end of the first sweep, and would include a downleg, an upleg, and then a downleg back to TSF. The station would be given the parameters of the contingency sweep considerably prior to rise so that they would have sufficient time to plan for and implement it if necessary.

VI. Post-Flight Analysis of the Viking 1 Launch Phase

A. Tracking Predictions

1. New PCT/PREDIK system. The PCT/PREDIK predicts generation system functioned smoothly during

the launch of Viking 1. Following the PCT generation scheme shown in Fig. 4, the Viking FPAG delivered PCT No. 1 at launch minus 4 hours 25 minutes. The stations were therefore able to receive the predicts necessary for generating a drive tape (predicts set A20D) well ahead of schedule. Additionally, since no changes were made to the frequencies provided by the Orbiter Performance Analysis Group (OPAG), it was decided not to generate the planned frequency predicts (predicts set A20F).

All remaining possible predict generation throughput time problems were alleviated when the launch occurred within a fraction of a second of the expected time.

Only one set of predicts (predicts set A20E) had to be generated between launch and spacecraft rise; this set was to give the station predicts with a GMT time field. (All previous text predicts were generated in time from launch.) Thus, while the PCT/PREDIK generation scheme had been carefully planned to handle any launch situation, the optimum situation (i.e., nominal countdown and launch) occurred, alleviating the problem of getting actual liftoff predicts to DSS 42 prior to spacecraft rise.

2. Prediction accuracy. During the early portion of the DSS 42 launch pass, the radio metric data, when differenced with the preflight nominal predict set A20E by the Network Operations Control Center (NOCC) pseudo-residual program, produced the following residuals:

$$\Delta HA \sim -0.07 \text{ deg}$$

$$\Delta D2 \sim 10 \text{ Hz (S-band)}$$

$$\Delta XA \sim -0.3 \text{ Hz (VCO)}$$

These can be compared to the 3σ uncertainties presented in Section II:

$$\Delta HA \sim 0.002 \text{ deg}$$

$$\Delta D2 \sim 10 \text{ Hz (S-band)}$$

$$\Delta XA \sim 55 \text{ Hz (VCO; total frequency/trajectory uncertainty)}$$

The residuals were generally within the 3σ uncertainties. While it substantially exceeded the 3σ uncertainty, the hour-angle residual caused no impact on the acquisition of the downlink and no degradation of the received signal level. Additionally, from a historical perspective, this was perhaps the smallest early launch

pass hour-angle residual yet achieved. The two-way doppler residuals (Fig. 6) started quite large (approximately −70 Hz) but gradually decreased to approximately the 3σ value of 10 Hz as the apparent motion of the spacecraft approached sidereal rate.

Considering the many possible sources of error, both in frequency and in trajectory, the miniscule difference between the measured and predicted best lock frequencies, ΔXA, indicates that the reference frequency supplied by the OPAG was highly accurate. Additionally, since the difference between predicted and measured best lock frequencies was smaller than the 3σ uncertainty supplied by OPAG by more than two orders of magnitude, one must consider that perhaps the 3σ frequency uncertainty calculations were overly pessimistic.

B. One-Way Acquisition at DSS 42

The Viking 1 one-way downlink was acquired by DSS 42 at 22:10:05 GMT, 33 seconds before the predicted 22:10:38 GMT spacecraft rise time. Subsequent stereographic plots of the spacecraft trajectory indicate a possible 1.5-degree hour-angle error in the horizon mask used in the predicts software. Considering the rate of change of hour angle that occurred during this period (approximately 0.04 degree per second), this error would seem to account for the discrepancy in the rise time.

The downlink acquisition is depicted in Fig. 7. As can be seen in this plot, the receiver appears to have been drifting in the region around a one-way doppler frequency of 1047000 Hz prior to expected acquisition time. The signal was apparently detected at 22:09:51 GMT with receivers reported in lock at 22:10:05 GMT, though both monitor and tracking data indicate possible continuous receiver lock as early as 22:09:53 GMT.

C. Two-Way Acquisition at DSS 42

DSS 42 was instructed by means of the acquisition message shown in Fig. 8 to perform the following uplink acquisition sweep:

Transmitter on:	22:13:40 GMT
Start sweep:	22:14:00 GMT
Starting frequency:	21.996130 MHz (VCO)
Sweep rate:	3 Hz/s (VCO)
End sweep:	22:15:30 GMT
Ending frequency:	21.996400 MHz (VCO)
Sweep duration:	90 seconds

A comparison of the instructed sweep and the sweep as actually performed can be seen in Fig. 5. As can be seen, the uplink sweep began approximately 8 seconds later than planned. The switch to the two-way, coherent mode occurred at 22:14:49 GMT, within 5 seconds of the expected time. After an extensive search that included momentarily (~4 seconds) locking onto the telemetry subcarrier (see Table 2), the two-way downlink was acquired at 22:15:19 GMT. Even after the late start, the station was able to complete the uplink sweep within one second of the planned 22:15:30 time. The tuning rate averaged a commendable 3.2 Hz/s.

D. Angle Tracking

In adherence to the angle drive strategy as outlined in Section IV, the antenna at DSS 42 was initially computer-driven, using the preflight nominal predict set A20D, generated at launch minus two hours.

The drive mode was successfully changed to autotrack at 22:15:40 GMT, 9 seconds after completion of the uplink acquisition sweep.

In preparation for an uplink transfer from DSS 42 to DSS 44, the drive mode was changed to computer mode at 23:00:00 GMT. At 23:07:50 GMT, after maser No. 1 had been switched into the Antenna Microwave Subsystem and the uplink transferred back to DSS 42, auto-tracking was resumed at DSS 42.

E. Ranging

Commencing at 01:10:02 GMT (August 21), DSS 42 began the acquisition of ranging data via the Planetary Ranging Assembly (PRA). Using the newly developed "Pseudo-DRVID" PRA ranging validation technique (see Ref. 2), it was rapidly apparent to the Network Operations Analysis Group, Tracking (NOAG TRK), that the PRA data were suspect, and this information was disseminated. Several hours later, after the FPAG had fit the PRA data, the problem (symptom) was identified—the $T0$s (acquisition times) were approximately 0.9 second early. This symptom could have been identified by the NOCT far more quickly via additional analysis of Pseudo-DRVID output; unfortunately due to the newness of the technique, not all of the Pseudo-DRVID analysis capabilities were known. As regards a constant error in $T0$, one can easily derive a relationship between the time offset and the Pseudo-DRVID output. Using the notation from Ref. 2 and additionally defining the following:

$$Pseudo\text{-}DRVID' = \Delta PRA' - \Delta DOP$$

$$\Delta PRA' = \Delta PRA(t'_b, t'_a)$$

$$t'_b = t_b + \Delta t$$

$$t'_a = t_a + \Delta t$$

one gets

$$Pseudo\text{-}DRVID' = \Delta PRA' - \Delta DOP$$
$$= \Delta PRA(t'_b, t'_a) - \Delta DOP(t_b, t_a)$$

and

$$\Delta PRA(t'_b, t'_a) = \Delta PRA(t_b + \Delta t, t_a + \Delta t)$$
$$= \frac{c}{48(TSF)} \{PRTR(t_b + \Delta t)$$
$$- PRTR(t_a + \Delta t) + Y\}$$

Now

$$PRTR(t_b + \Delta t) = PRTR(t_b) + \{PRTR(t_b + \Delta t)$$
$$- PRTR(t_b)\}$$

and

$$PRTR(t_a + \Delta t) = PRTR(t_a) + \{PRTR(t_a + \Delta t)$$
$$- PRTR(t_a)\}$$

so that

$$\Delta PRA(t'_b, t'_a) = \frac{c}{48\,(TSF)} [PRTR(t_b)$$
$$- PRTR(t_a) + Y$$
$$+ (\{PRTR(t_b + \Delta t) - PRTR(t_b)\}$$
$$- \{PRTR(t_a + \Delta t) - PRTR(t_a)\})]$$

$$= \Delta PRA(t_b, t_a)$$

$$+ \frac{c}{48(TSF)} (\{PRTR(t_b + \Delta t)$$
$$- PRTR(t_b)\}$$
$$- \{PRTR(t_a + \Delta t) - PRTR(t_a)\})$$

and

$$Pseudo\text{-}DRVID' = \Delta PRA(t_b, t_a) - \Delta DOP(t_b, t_a)$$

$$+ \frac{c}{48(TSF)} (\{PRTR(t_b + \Delta t)$$
$$- PRTR(t_b)\}$$
$$- \{PRTR(t_a + \Delta t) - PRTR(t_a)\})$$

$$= \text{Pseudo-DRVID}$$

$$+ \frac{c}{48(TSF)} (\{PRTR(t_b + \Delta t)$$

$$- PRTR(t_b)\}$$

$$- \{PRTR(t_a + \Delta t) - PRTR(t_a)\})$$

Since

$$\frac{c}{48(TSF)} PRTR(t) = RTR(t)$$

and using the definition of a derivative

$$\frac{f(x + \Delta x) - f(x)}{\Delta x} \cong \frac{df}{dx}$$

one has

$$\frac{c}{48(TSF)} (\{PRTR(t_b + \Delta t) - PRTR(t_b)\}$$

$$- \{PRTR(t_a + \Delta t) - PRTR(t_a)\})$$

$$= \{RTR(t_b + \Delta t) - RTR(t_b)\}$$

$$- \{RTR(t_a + \Delta t) - RTR(t_a)\}$$

$$\cong \left(\frac{dRTR}{dt}\right)_{t_b} \Delta t - \left(\frac{dRTR}{dt}\right)_{t_a} \Delta t$$

$$\cong \Delta t \left\{ \left(\frac{dRTR}{dt}\right)_{t_b} - \left(\frac{dRTR}{dt}\right)_{t_a} \right\}$$

Now

$$D2 = 96 \frac{240}{221} TSF \left(\frac{2\dot{r}}{c}\right) + 10^6 \quad \text{(Block III Receiver)}$$

$$= 96 \frac{240}{221} TSF \left(\frac{1}{c}\left[\frac{dRTR}{dt}\right]\right) + 10^6$$

or

$$\frac{dRTR}{dt} = \frac{c(D2 - 10^6)}{96 \frac{240}{221} TSF}$$

so that

$$\Delta t \left\{ \left(\frac{dRTR}{dt}\right)_{t_b} - \left(\frac{dRTR}{dt}\right)_{t_a} \right\}$$

$$\cong \Delta t \frac{c}{96 \frac{240}{221} TSF} \{[(D2)_{t_b} - 10^6] - [(D2)_{t_a} - 10^6]\}$$

$$\cong \frac{c\Delta t}{96 \frac{240}{221} TSF} \{(D2)_{t_b} - (D2)_{t_a}\}$$

which is to say, finally,

$$\text{Pseudo-DRVID}' \cong \text{Pseudo-DRVID}$$

$$+ \frac{c\Delta t}{96 \frac{240}{221} TSF} \{(D2)_{t_b} - (D2)_{t_a}\}$$

If one ignores Pseudo-DRVID (i.e., considers it small compared to any timing error contribution), one would have:

$$\Delta t \approx 96 \frac{240}{221} \left(\frac{TSF}{c}\right) \left\{ \frac{\text{Pseudo-DRVID}'}{[(D2)_{t_b} - (D2)_{t_a}]} \right\}$$

Below are presented the Pseudo-DRVID results from the DSS 42 launch pass, and calculations of Δt offsets using the above equation:

Acquisitions	Pseudo-DRVID, RU	Δt, seconds
1/2	188	−0.92
2/3	161	−0.87
3/4	174	−1.00
4/5	136	−0.82
5/6	138	−0.89
6/7	132	−0.90

The above results clearly demonstrate the ability of the Pseudo-DRVID technique to detect PRA "timing" errors in the near-real-time operations environment.

The malfunction which resulted in the −0.9-second error in $T0$ was not identified until several days later. At that time, it was found that the receiver coder in the Ranging Logic Assembly was being synchronized onto the trailing edge of the 10% duty cycle 1 pps, rather than the leading edge as it should properly have been. The problem was cleared by readjusting the threshold level of an isolation amplifier in the Frequency and Timing Subsystem (FTS), which supplies the 1 pps to the PRA.

VII. Summary of Tracking Operations During the Viking 1 Launch Phase

Viking 1 launch phase tracking operational procedures, and in particular the DSN initial acquisition procedures, were very intensively considered and conservatively designed to accommodate even the most unfavorable of launch possibilities. These procedures were successfully implemented, and strongly contributed to the highly successful launch phase of the Viking 1 mission.

Acknowledgment

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2. Berman, A. L., "Pseudo-DRVID: A New Technique for Near-Real-Time Validation of Ranging System Data," in *The Deep Space Network Progress Report 42-29*, pp. 180–187, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1975.

Table 1. Description of predicts denoted by Z

Z	Description	PCT generated
O	Open window predicts	$L - 7$ days[a]
M	Mid window predicts	$L - 7$ days[a]
C	Close window predicts	$L - 7$ days[a]
P	Parking orbit predicts	$L - 7$ days[a]
F	Frequency update predicts	$L - 165$ min
D	Drive tape predicts	$L - 165$ min
E	Estimated launch time predicts	$L - 10$ min
A	Actual launch time predicts	$L + 5$ min
B	Burn (TMI) estimate predicts	$L + 20$ min
N	No TMI burn predicts	$L + 25$ min
I	Injection estimate predicts	$L + 50$ min

[a]To be regenerated at $L - 24$ hours if launch slips.

Table 2. Doppler residuals

| GMT	Residual	Comments
22:13:30	34.416	Final one-way residual
22:14:00	−9420.715	Tuning—one-way doppler flagged two-way
22:14:10	−9163.489	Tuning
22:14:20	−6156.806	Tuning
22:14:30	−3037.731	Tuning
22:14:40	222.214	Tuning
22:14:49	−2280.683	Receiver out of lock—switch to coherent mode
22:15:00	−24066.756	Receiver locked on telemetry subcarrier
22:15:02	−24065.680	Receiver locked on telemetry subcarrier
22:15:19	−68.254	Receiver locked on carrier— good two-way
22:16:00	−66.052	Good two-way residual
22:18:00	−50.027	Good two-way residual
22:20:00	−37.420	Good two-way residual
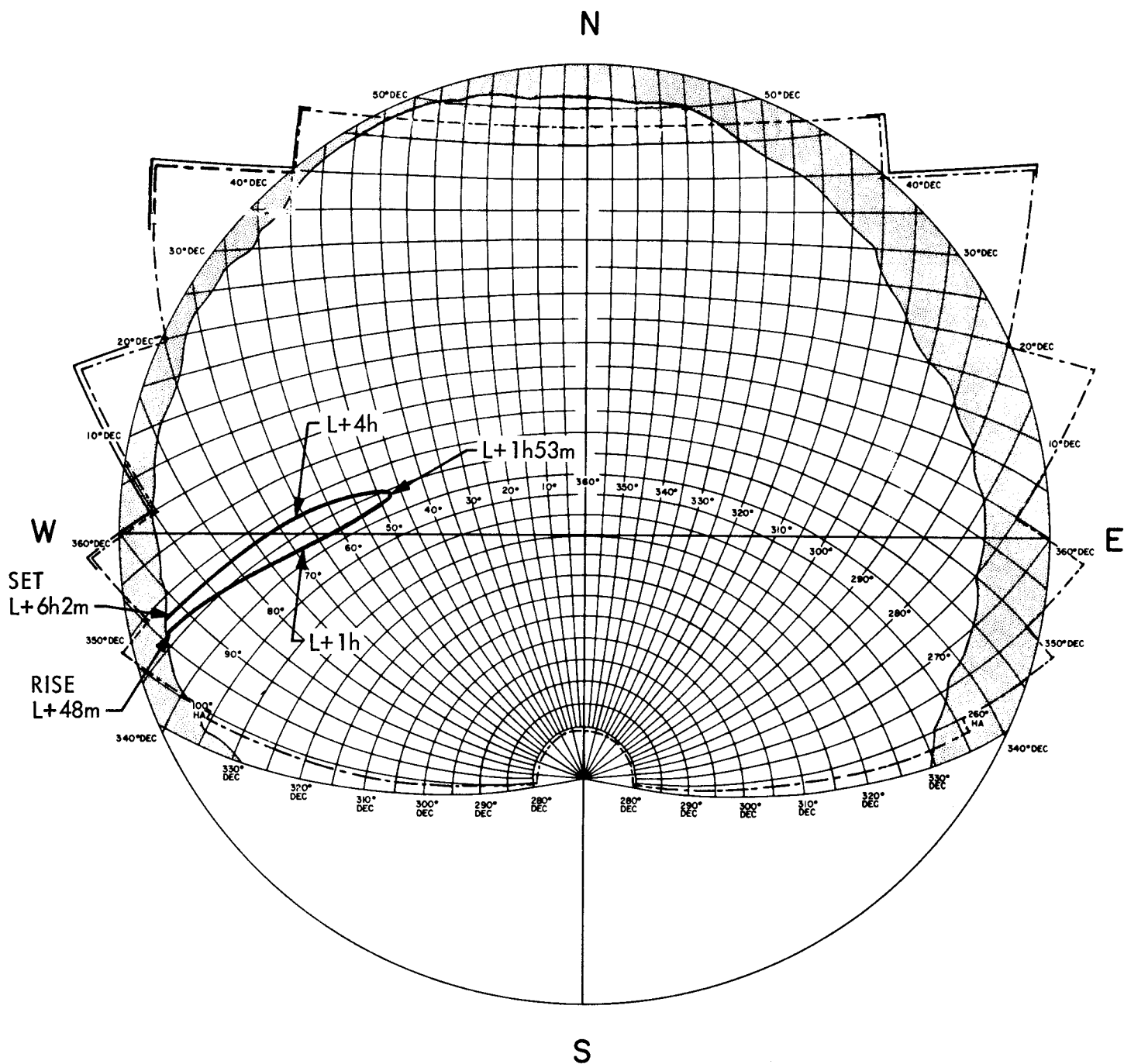
Fig. 1. DSS 42 Viking 1 launch, August 20, 1975
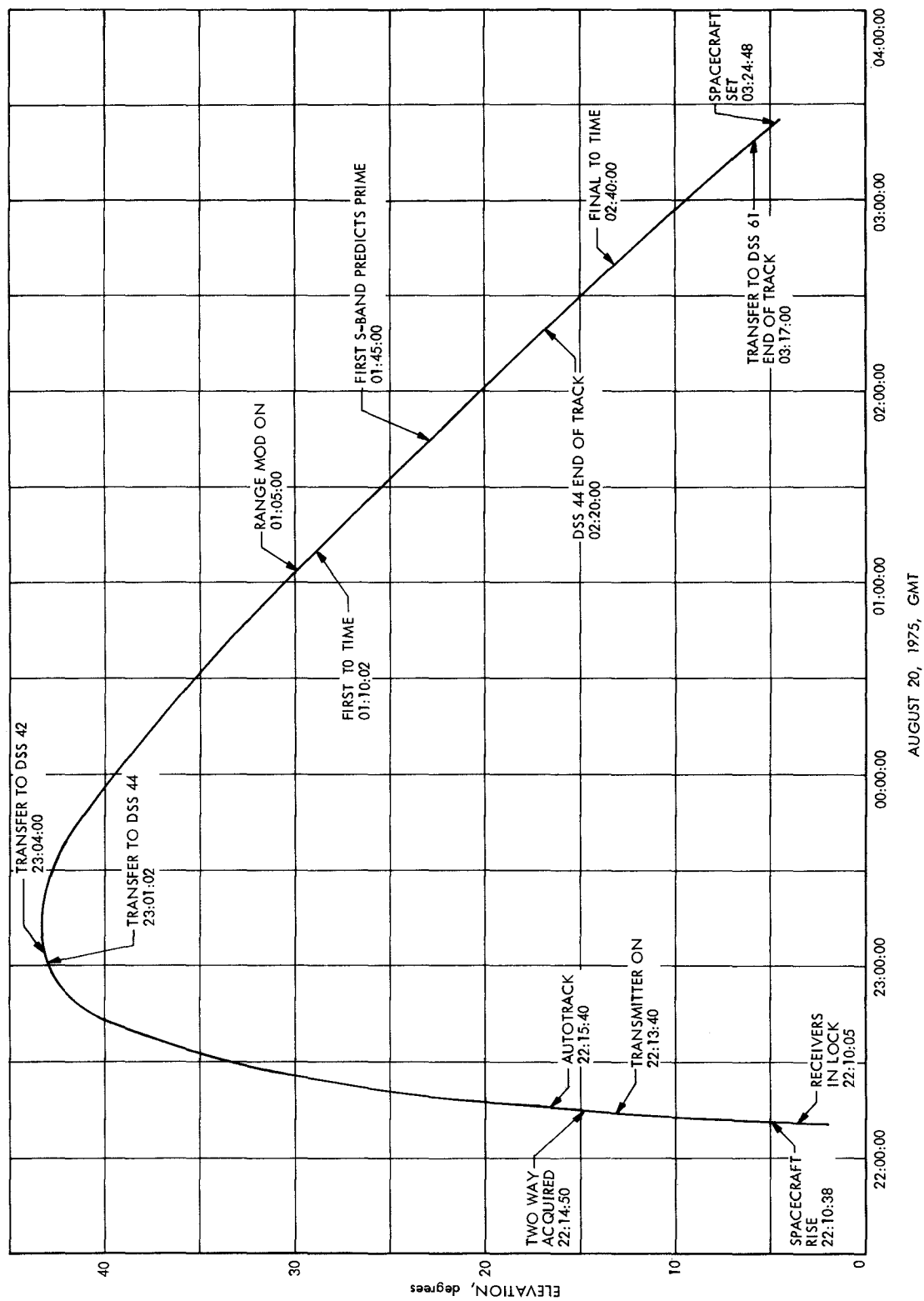
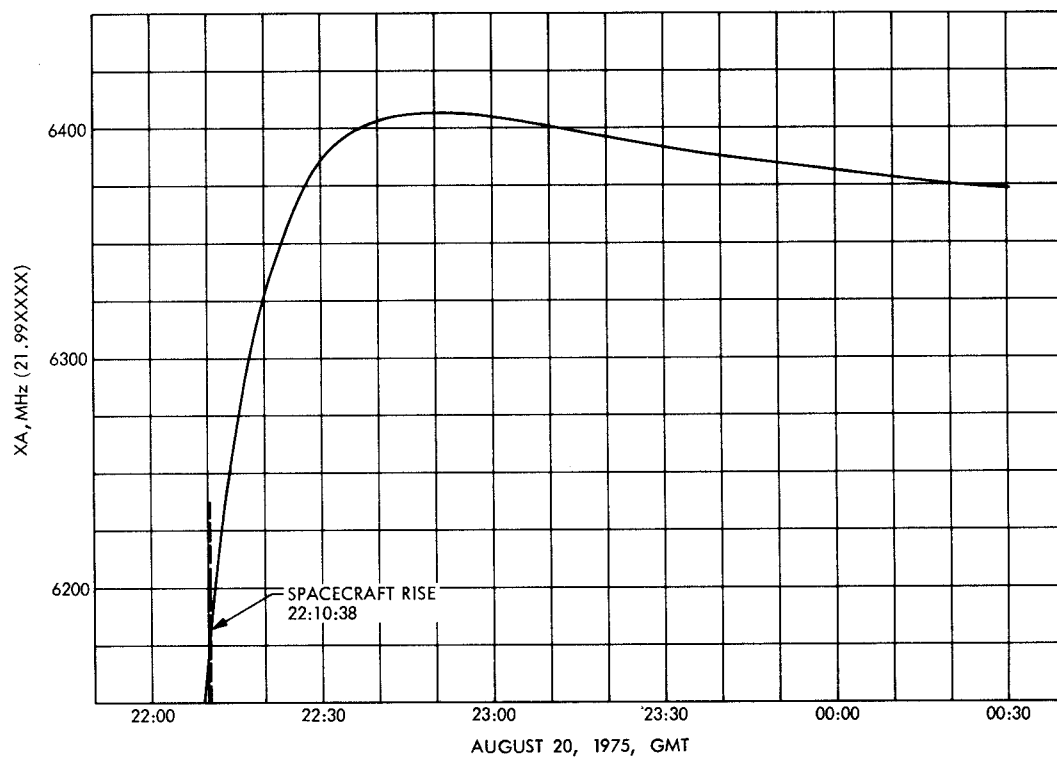Fig. 2. Spacecraft elevation at DSS 42 Viking 1 launch

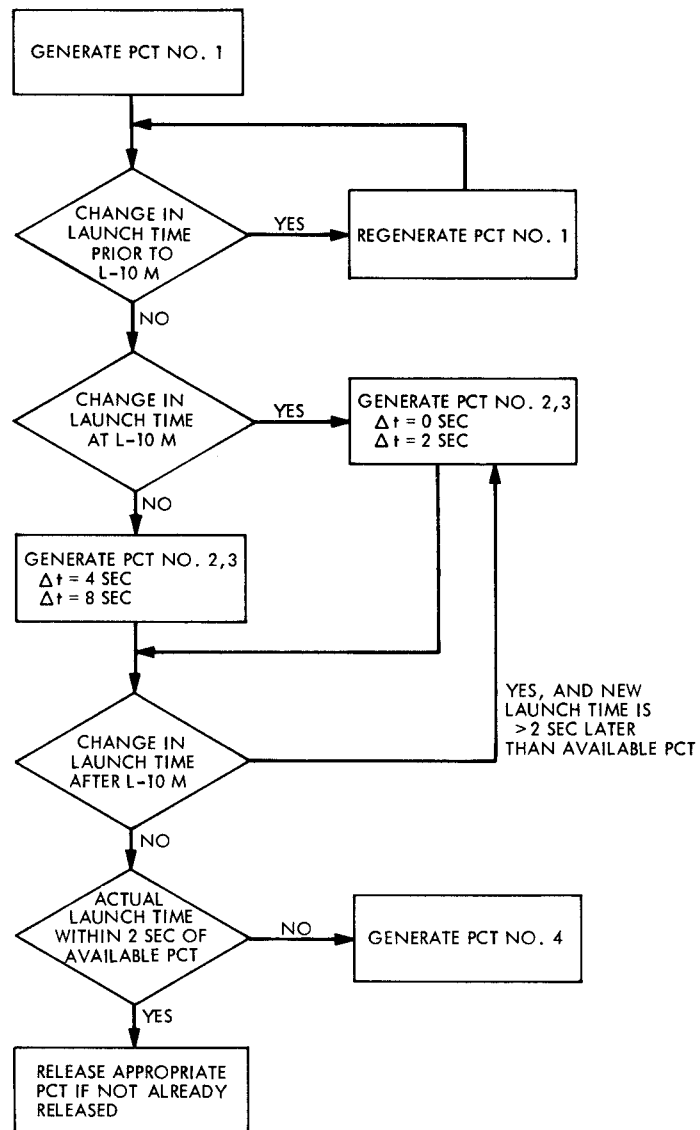Fig. 3. Best-lock frequency at DSS 42 Viking 1 launch

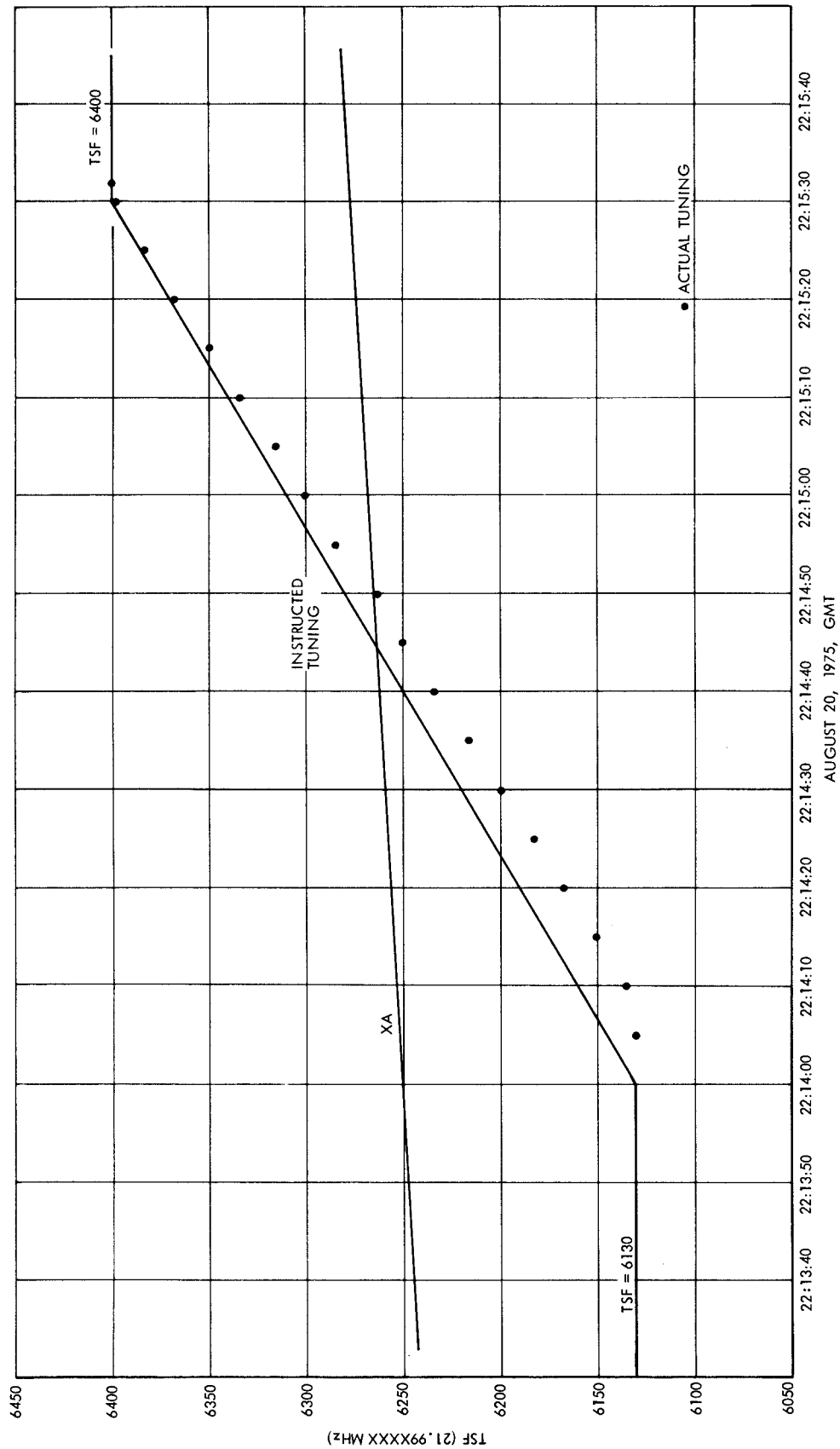Fig. 4. PCT generation scheme

Fig. 5. Comparison of actual tuning to instructed tuning at DSS 42 Viking 1 launch
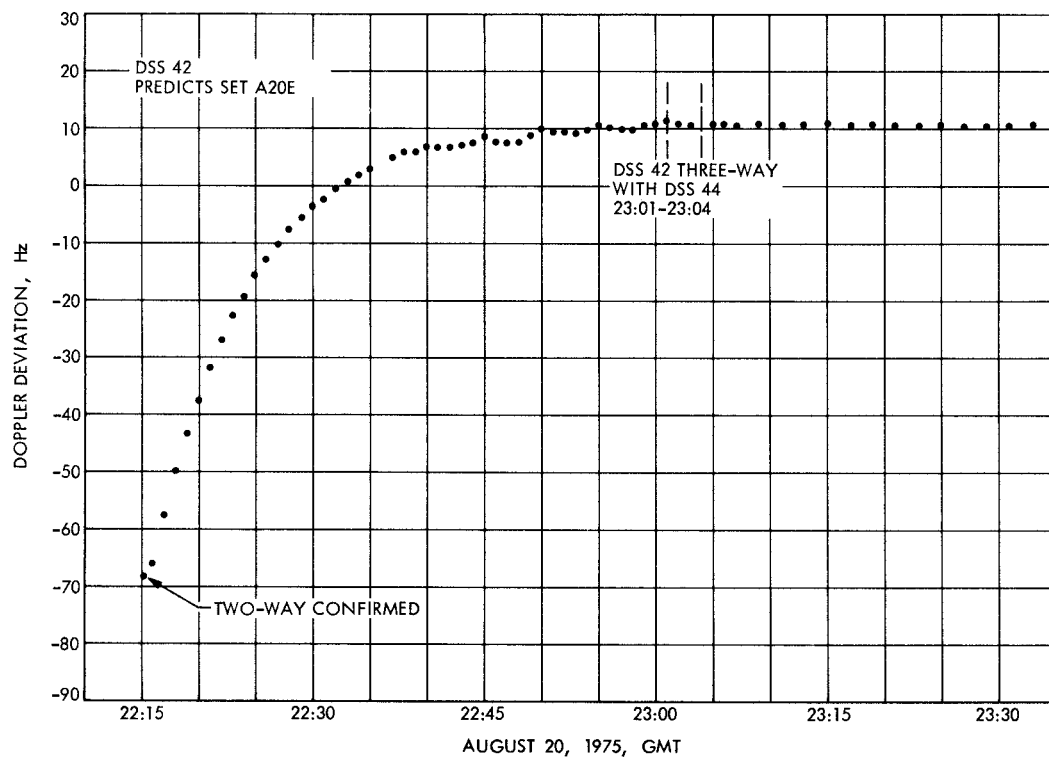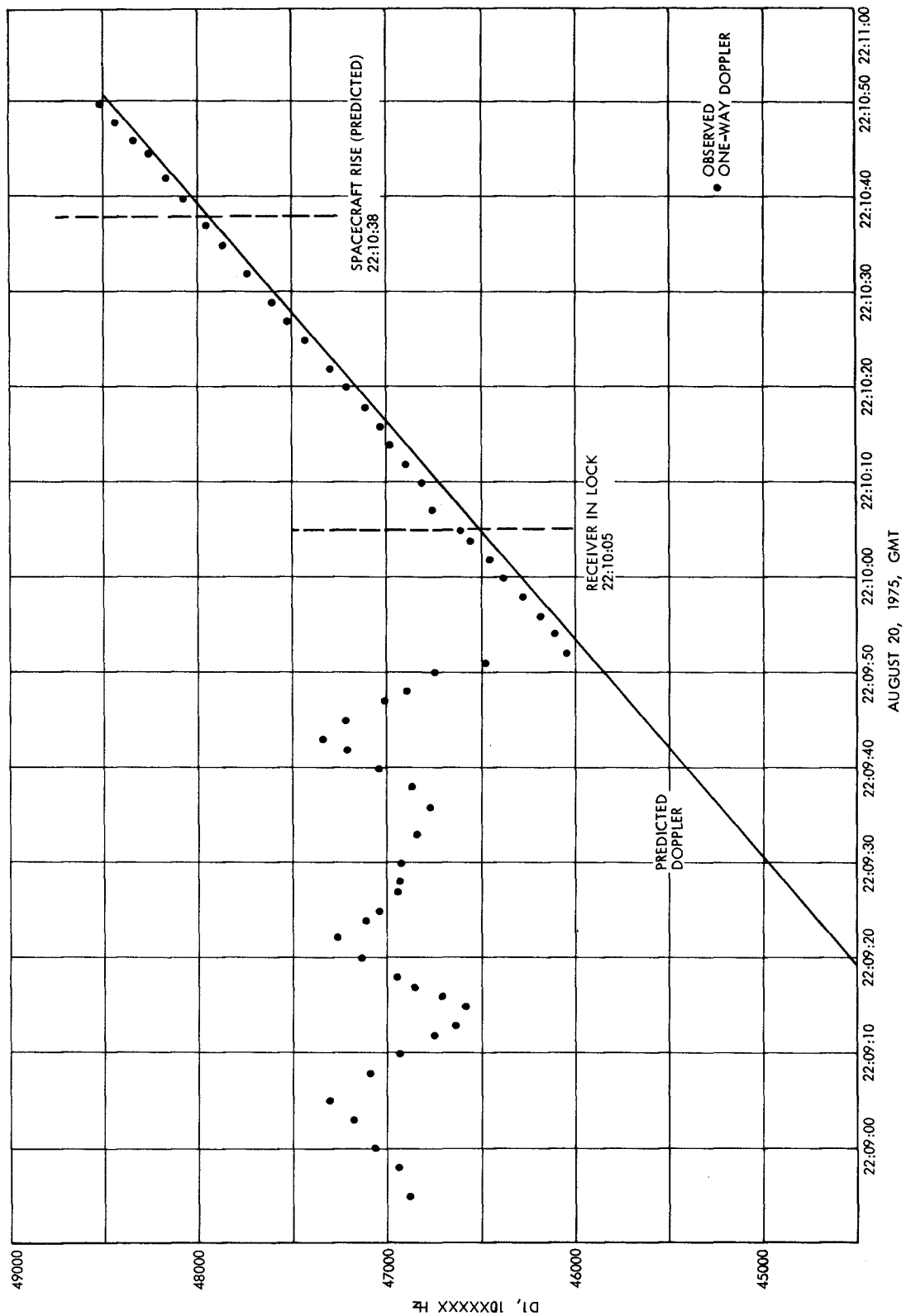
Fig. 6. Doppler deviation from preflight nominal predicts

Fig. 7. Initial downlink acquisition at DSS 42 Viking 1 launch

VIKING INITIAL ACQUISITION DSS ___42___ VERSION ___3___

A. PREDICTS

1.	TEXT	A20E	IS PRIME
2.	DRIVE TAPE	A20D	IS PRIME
3.	HA/X BIAS	—	DEG
4.	DEC/Y BIAS	—	DEG
5.	APS TIME BIAS	—	GMT

B. INITIAL UPLINK ACQUISITION SWEEP

6.	TXR ON	22:13:40	GMT
7.	TXR POWER	10	KW
8.	FREQUENCY	21.996130	MHZ
9.	START TUNING	22:14:00	GMT
10.	TUNING RATE	180	HZ/MIN(VCO)
11.	TRACK SYN FREQ	21.996400	MHZ
12.	CMD MOD ON	—	GMT

C. CONTINGENCY SWEEP: EXECUTE ONLY IF DIRECTED

13.	START TUNING	22:19:00	GMT
14.	TUNING RATE	180	HZ/MIN(VCO)
15.	SWEEP DOWN TO	21.996160	MHZ
16.	SWEEP UP TO	21.996510	MHZ
17.	SWEEP DOWN TO TSF	21.996400	MHZ
18.	CMD MOD ON	—	GMT

SPECIAL INSTRUCTIONS:

Fig. 8. Actual Viking 1 acquisition message